Arnold Schwarzenegger
Governor

REVIEW OF INTERNATIONAL EXPERIENCE INTEGRATING VARIABLE RENEWABLE ENERGY GENERATION

APPENDIX C: INDIA

PIER PROJECT REPORT

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Preface

The Public Interest Energy Research (PIER) Program supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

The PIER Program, managed by the California Energy Commission (Energy Commission) conducts public interest research, development, and demonstration (RD&D) projects to benefit the electricity and natural gas ratepayers in California.

The PIER program strives to conduct the most promising public interest energy research by partnering with RD&D organizations, including individuals, businesses, utilities, and public or private research institutions.

PIER funding efforts are focused on the following RD&D program areas:

- Buildings End-Use Energy Efficiency
- Energy Innovations Small Grants
- Energy-Related Environmental Research
- Energy Systems Integration
- Environmentally Preferred Advanced Generation
- Industrial/Agricultural /Water End-Use Energy Efficiency
- Renewable Energy Technologies
- Transportation

Review of International Experience Integrating Variable Renewable Energy Generation, Appendix C: India is the final report for a subtask of Task 3 for the PIER Intermittency Analysis Project (IAP), contract number 500-02-004, work authorization number MR-017, conducted by the IAP team comprised of the California Wind Energy Collaborative, Exeter Associates, BEW Engineering, Davis Power Consulting, and GE Energy Consulting (with assistance from AWS Truewind, National Renewable Energy Laboratory (NREL), Oak Ridge National Laboratory (ORNL), and Rumla Consulting). The information from this project contributes to PIER's Renewable Energy Technologies program.

For more information on the PIER Program, please visit the Energy Commission's website at www.energy.ca.gov/pier or contact the Energy Commission at (916) 654-5164.

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Abstract

This report summarizes the experience in India through 2006 with integrating variable renewable energy generation, primarily wind generation, and discusses potential operating and mitigation strategies for incorporating variable renewable energy generation. Initially, wind development in consisted of smaller but numerous wind projects interconnected to the distribution grid, in contrast with larger, utility-scale wind projects interconnected to the transmission grid in the United States. The differences between other countries and the United States are starting to narrow as development of variable renewable energy generation (e.g. wind and solar) increases and as wind development takes place in more countries. In addition, as more utility-scale wind projects emerge, more countries are relying on common strategies, such as grid codes, to help integrate variable renewable energy generation. This report is a part of the Intermittency Analysis Project (IAP), a comprehensive project aimed at assessing the impact of increasing penetration of variable renewable energy generation in California. A review of the international experience will provide perspective and insight to the IAP analysis team on various techniques for managing intermittency.

Keywords: grid code, renewable energy generation, reserves, transmission, wind forecasting, wind integration.

1.0 India Profile

With an installed wind power capacity of more than 6,000 megawatts (MW) in December 2006, India has quickly risen to be the fourth largest wind market in the world (Table 1, Figure 1) (Global Wind Energy Council 2007).[1] After adding more than 1,000 MW of wind capacity annually between 2004 and 2006, India has already exceeded its 2012 target of 5,000 MW installed wind capacity (Rajgor and Mathews 2006). Wind resource assessments sponsored by the national government have identified favorable wind resources in 10 of the western and southern states of India. According to the Centre for Wind Energy Technology (C-WET), India's large coastal and desert areas along with some interior hilly terrain have the potential to provide more than 45,000 MW of wind power across 10 states (Centre for Wind Technology 2005). The mountainous regions of the north and northwest may also have suitable wind resources for utility size power projects, but due to civil unrest and a lack of interest by developers, these regions have not been the subject of government wind resource assessment studies. The Ministry of Non-Conventional Energy Sources (MNES) recently launched a wind resource assessment program in the northeastern region of the county that may identify additional resources. Of the 10 states with identified wind resources, Orissa is the only state not to have developed a wind project.

1. Note that the wind capacity data in the first sentence on this page will differ from the wind capacity data in Table 1 and Figure 1. Table 1 summarizes installed wind capacity as of September 30, 2006, while Figure 1 depicts installed wind capacity in India as of March 30, 2006.

Table 1. Installed wind capacity as of September 30, 2006 (MW)

State	Demonstration or Public Sector Wind Projects	Private Sector Wind Projects	Installed Wind Capacity	Total Installed Capacity	Percent of Capacity that is Wind
Andhra Pradesh	5.4	115.6	121.0	11,642.44	1.0%
Gujarat	17.3	358.3	375.6	10,269.87	3.7%
Karnataka	7.1	577.5	680.4	7,784.69	8.8%
Kerala	2.0	0.0	2.0	3,496.44	*
Madhya Pradesh	0.6	52.4	53.0	6,486.75	*
Maharashtra	8.4	1,33.3	1,241.7	17,380.23	7.1%
Rajasthan	6.4	351.7	358.1	5,490.65	7.0%
Tamil Nadu	19.4	2,873.1	2,892.5	12,375.64	25.4%
West Bengal	1.1	0.5	1.6	5,330.99	*
Others	1.6	1.6	1.6	--	--
Total (All India)	69.3	5,948.4	6,017.7	128,182.47	4.7%

* Less than 1 percent

Sources: Ministry of Non-Conventional Energy Sources. "State-Wide Wind Power Installed Capacity in India." http://www.windpowerindia.com/statstate.html. (accessed February 26, 2007).

Rajgor, Gail and Neelam Mathews. "India Close to 2012 Wind Target: New National Policyh and Grid Investment." *Windpower Monthly* (March 2006): 44.

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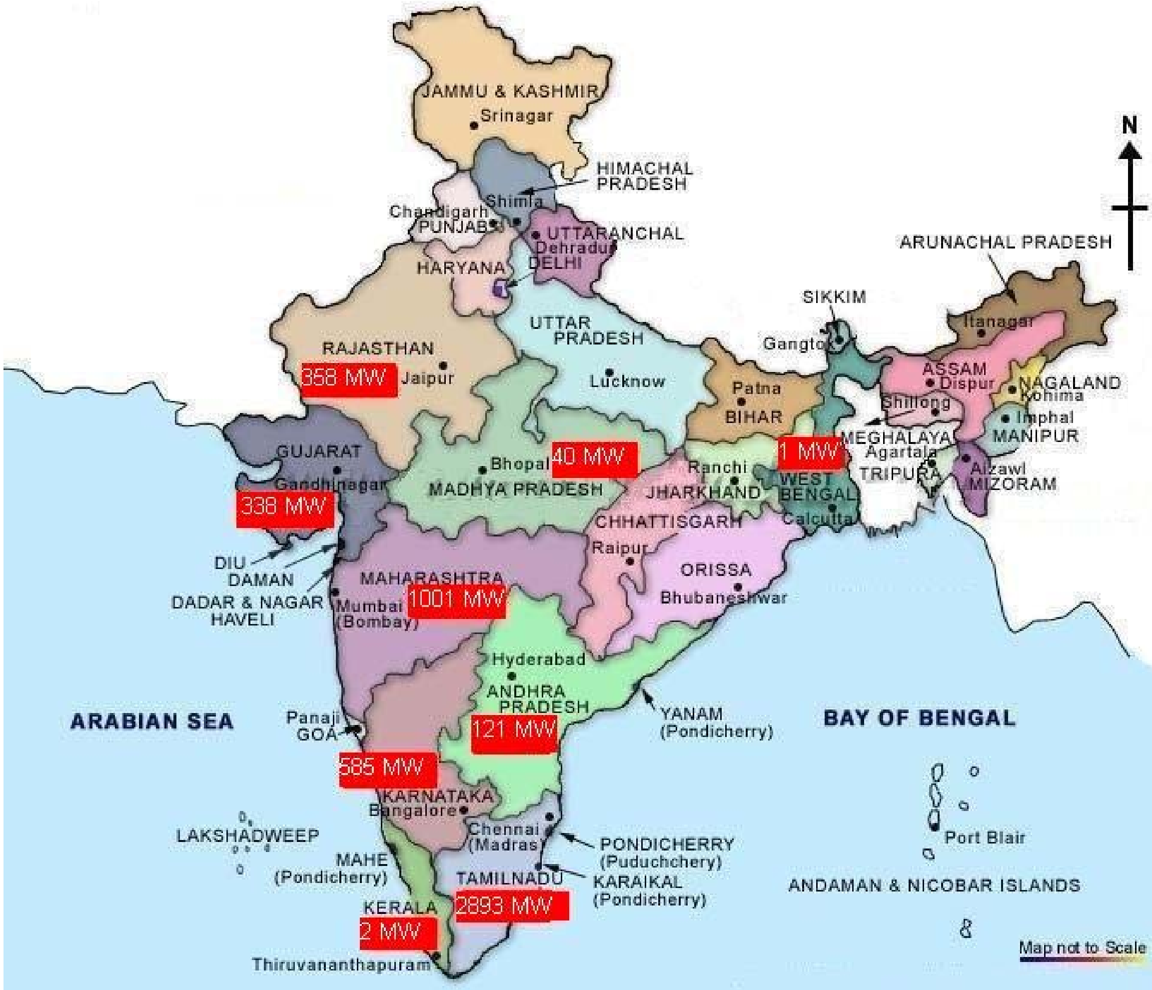

Figure 1: Installed Wind Capacity in India as of March 30, 2006

Source: Sources: Ministry of Non-Conventional Energy Sources. "State-Wide Wind Power Installed Capacity in India." http://www.windpowerindia.com/statstate.html. (accessed February 26, 2007).

The Indian Electricity Act of 2003 helped encourage wind power development by stating that utilities should purchase wind power as it becomes available. The Act also allows for third party sales of electricity, subject to regulation of the state electricity regulatory commissions, and requires state regulatory commissions to ensure open and non-discriminatory transmission access to wind power producers as soon as possible. Furthermore, state load dispatch centers are to be upgraded so that they can better accommodate additional resources (Mathews 2005c).

Tax incentives established by the Government of India have also spurred investment in wind projects. Under Section 80IA of the Income Tax Act, wind developers are allowed accelerated depreciation of up to 80% of project costs in the first year and payment of the

Minimum Alternate Tax (MAT) for the first 15 years of the project.[2] These tax policies create a situation where companies use investments in wind power as part of their balance sheet financing, seeking the tax credits for their investment. The result is that while substantial capacity has been developed, plant efficiency has been largely ignored (Mathews 2005b).

In some instances, wind plants are not maintained or repaired as needed so that the actual production of electricity relative to installed capacity is quite low. There are nearly 55 different types of wind turbines from 30 different wind turbine manufacturers installed in India. Many of the manufacturers have gone out of business, making replacement parts hard to find and repairs difficult to complete (Rajsekhar and Van Hulle 2001). Furthermore, independent power producers and foreign institutional investors that do not have a significant tax burden in India are not participating in the market. The Indian Wind Energy Association has been lobbying to change the incentive structure to a production tax credit to encourage more efficient production of electricity.

Apart from the tax credits, companies are allowed under the Indian Electricity Act of 2003 to produce power for their own use under and run the power through the grid. Such self-suppliers have to surrender between 4% and 18% of the power transmitted, depending on the state. However, those self-suppliers are supplied longer from the grid and are cut off later if power shortages occur. For these reasons, many customers of wind companies in India are textile and steel industries.

The power system of India is divided into five subsystems, the Northern, North Eastern, Southern, Eastern and Western Regional Grids. The majority of the wind resources in India are located within the Southern Regional Grid, including the states of Tamil Nadu, Kerala, Karnataka, and Andrah Pradesh; and the Western Regional Grid, made up of Goa, Daman and Diu, Chhatisgarh, Dadar and Nagar Haveli, Gujarat, Maharashtra, and Madhya Pradesh. Each state owns their power system, which is managed by a state electricity board. Wind farms are concentrated in rural areas, where transmission and distribution grids tend to be very weak and often lack the capacity to tie-in large amounts of wind power.

The insufficient capacity of the power system can cause large variations in steady-state voltage and power outages. Indeed, the Indian government estimates the economic damage caused by power outages at $25 billion annually (Sieg 2006). Substations are not always equipped with automatic voltage regulation, further adding to the complications and instability. The Indian electric standards for the transmission grid set a tolerance band of +/- 12.5% steady state voltage. Observations in Gujarat indicate that wind turbines connected to weak grids may have a difficult time staying within this band.

2. Companies that show book profits as per their profit and loss account but were not paying any taxes because of dividend payouts or other tax provisions are required to pay 30% of book profits as the minimum alternate tax.

Inadequate grid capacity and equipment affects both the efficiency and operation of the wind turbine. The performance of wind turbines is influenced by grid outages, frequency, voltage imbalances, and steady-state voltage. Wind power output is reduced in grid outages simply because turbines go off-line in an outage. Frequency variations lead to changes in rotor speed, subsequently impacting performance and output. This can be corrected with the use of a converter. Voltage imbalances can cause the turbine to trip off-line, and lead to efficiency losses in induction generators. The weak Indian grid networks can exacerbate these problems, making development difficult for rural areas with insufficient grid capacity (Sorensen 2005).

India does not have a national grid. Instead, the country is a patchwork of local networks designed to serve specific populations, some of which may be interconnected within state and regional grid systems. The Indian Electricity Grid Code provides the rules, guidelines and standards to be followed by participants, including generators and transmission operators, for grid operation. The Central Electricity Regulatory Commission issues the National Grid Code which applies to all utilities connected to the inter-state transmission system, as well as the Regional and State Load Dispatch Centres. Only those generators who provide electricity for use in more than one state are subject to the provisions of the National Grid Code. The majority of generators serve loads in only one state and are therefore subject to the provisions of the specific State Grid Code. Furthermore, wind facilities may negotiate different terms and operating conditions than what is required by state grid codes as part of their power purchase agreement with the state electricity board (Dalal 2006).

There are plans to build a national grid, with capabilities to conduct inter-regional transfers, by 2012. India's lack of a national grid is a major constraint to wind power development. The MNES estimates the potential wind capacity at 45,000 MW while the technical capacity is just 13,000 MW due to limited transport capacity of the grid (Ministry of Non-Conventional Energy Sources 2005). At times, even well-functioning wind turbines are idle because the grid is overloaded or is under repair (Sieg 2006). In several cases, wind plant developers and manufacturers have pooled resources to make necessary gird investments, such as constructing new or upgraded substations, to ensure transmission of their electricity.

The Centre for Wind Energy Technology (CWET) initiated a research project in 2005 to model the interconnection of wind turbines with the grid. The research and development unit of CWET is developing a model to study the behavior of the grid as wind farms come on-line and to make recommendations for planning and control strategies for improved grid security (Centre for Wind Energy Technology 2005).

Thus far, India does not have a comprehensive renewable energy policy or regulatory framework with legally binding targets for renewable resources. The majority of the policies and incentives for wind power are established at the state level and industry supporters worry that growth will slow without some action on the part of the Federal Government. Specifically needed are policies to create better grid infrastructure, regulation, and system management, along with grid codes that address the characteristics of renewable resources.

As a start, the Ministry of Power issued a new Tariff Policy on non-conventional sources of energy generation, including wind power, on January 6, 2006. The policy requires each state commission to establish, "a minimum percentage for purchase of energy from such sources taking into account availability of such resources in the region and its impact on retail tariffs." The policy further instructs that utilities should use a competitive bidding process to select the suppliers of non-conventional sources (including wind power) to meet the minimum requirement. The Central Electricity Regulatory Commission is charged with setting guidelines for pricing non-firm power in those cases where competitive bidding is not feasible (India Ministry of Power 2006). Overall, India plans to construct 100 GW of new capacity by 2012, of which 10% is to come from renewables, and half of that is to come from wind power, or 5,000 MW (Rajgor and Mathews 2006).

The majority of the policies encouraging and facilitating wind power development in India are either established at the state level, or are implemented at the state level as required by federal law. Table 2 summarizes the policies introduced in those states with identified wind resources.[3] The cost of wheeling wind power over the grid for sale to a third party varies by state. Essentially, the state electricity boards take a certain amount of the electricity sent to the grid as payment for wheeling, or transporting, the power. Specific information on Tamil Nadu and Maharashtra, the leading states in terms of installed wind power and policies addressing wind energy resources, is provided below.

3. Wind Resource Assessment studies have concluded that 10 states have sufficient resources for utility-scale wind power projects: Andhra Pradesh, Gujarat, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Orissa, Rajasthan, Tamil Nadu and West Bengal. All but Orissa have established policies supporting wind development.

Table 2: State Government Policies and Incentives for Wind Power Development

Policies/ Incentives	Andhra Pradesh	Gujarat	Karnataka	Kerala	Madhya Pradesh	Maharashtra	Rajasthan	Tamil Nadu	West Bengal
Wheeling	Same as with conventional energy	4% of energy	5% of energy + Rs.1.15/kWh as cross subsidy for 3rd party sale.	To be decided by SERC	2% of energy + transmission charges as per ERC	2% of Energy as wheeling + 5% as T&D loss.	Below 132 kV, 50% of normal charges applicable to 33 kV declared by commission plus surcharge plus losses	5% of energy	7% of energy plus open access charges
Wind Tariff Rates	Rs.3.37 per kWh (01/04/2004) (frozen for 5 years)	Rs.3.37 per kWh (without any escalation for 20 yrs.)	Rs. 3.40 per kWh without any escalation for 10 yrs of commercial operation	To be decided by SERC	Year wise rates (Rs./kWh) from 1st to 20th year 3.97, 3.80, 3.63, 3.40, 3.30, 3.30, 3.30, 3.30, 3.30, 3.30, 3.30, 3.30, 3.30, 3.30, 3.30, 3.30, 3.30, 3.30, 3.30, 3.30	Rs.3.50/kWh (First year of commissioning). (escalation of 15 paise per year for 13yrs)	First year 3.25/kWh then escalation of 6 paise per year unitl 10th year and then Rs.3.79/kWh from 11th to 20th year . Base year 2004-05, valid up to March 31, 2007.	Rs. 2.90 per kWh	Rs. 4 per kWh
Power Factor Penalties (kVArh /kWh)	10 paise per kVArh up to 10% & 25 paise per kVArh above 10%	10 paise per kVArh	Rs. 0.40 Per kVArh		27 paise per kVArh	25 paise per kVArh	4 paise per uear with escalation of 5% per year	25 paise per kVArh if the ratio of kVArh drawn to KWh exported is upto 10% and 50 paise per KVArh for more than 10%.	

Source: Wind Power India. *Policies Introduced/Incentives Declared by the State Governments for Private Sector Wind Power Projects*. http://www.windpowerindia.com/govtinc.html. (accessed February 28, 2007).

2.0 Tamil Nadu

Tamil Nadu is the undisputed leader in installed wind capacity in India. The textile market has helped drive the demand for wind power in this state. Under the Textile Upgradation Fund (TUF), loans are made available to assist the textile industry's modernization, including obtaining firm power supplies. This policy is further aided by a special lending rate of 12.5% for wind projects supplying electricity directly to business owners in Tamil Nadu, a state with a significant textile industry (Mathews 2005c). A result of the pairing of the textile industry and wind power developers is that a significant amount of power is used for captive consumption and is not sold onto the grid or to third-party buyers. However, the Finance ministry recently ruled that wind turbines could no longer benefit from the special loan program, stating that wind turbines are not textile machinery and they do not constitute modernization of the textile industry (Mathews 2005a).

The Tamil Nadu Grid Code includes several provisions specific to wind power generators connected to the intra-state grid. According to the grid code, wind generators are not required to schedule their generation with the state load dispatch center. At the same time, wind power has priority dispatch over nuclear and thermal resources. Furthermore, the grid code states that wind power should not be curtailed (Tamil Nadu Electricity Grid Code 2005). In a system where wind generators make up 20 percent of installed capacity, there is the potential for a large amount of unscheduled wind power to come on-line. However, the inefficiencies of the older, poorly maintained wind turbines and the number of wind turbines serving on-site industrial loads may serve to decrease the amount of wind power that actually comes onto the grid. Many of the wind projects constructed in Tamil Nadu were built as depreciation value projects and were not properly built, operated, or maintained (Dalal 2006). As older turbines are replaced and additional capacity comes on-line, Tamil Nadu may have to adjust this policy. The impact of wind energy generators on the performance of the power system is a specific consideration for generation planning as documented in the grid code.

3.0 Maharashtra

The state of Maharashtra has established several policies to help further wind development. With a goal of 750 MW installed by 2007, the Maharashtra Energy Department gives a priority to non-conventional energy sources, provides subsidies to developers, and tax breaks to industrial customers who purchase wind power. Maharashtra State Electricity Board plans to invest 1.5 million Rupees (about $33.8 million) to develop a 40 MW wind project to demonstrate their commitment to green power (Centre for Wind Energy Technology 2005). Further encouraging wind power development, a green energy fund was established to pay for 50% of the necessary transmission and distribution lines to transport wind energy. Interest free loans are available to help finance the remaining 50% of costs. Additionally, wind developers can pay for the transmission upgrades and receive the subsidy as a reimbursement from the state at a later date.

Maharashtra is also collecting a tax from all industrial customers to help cover the cost of electricity infrastructure projects, such as roads to remote wind farms and the construction of substations. The sale of wind power to third parties is allowed with a grid use charge levied at 2% of transmitted energy. Industries purchasing wind power are exempt from paying the standard electricity tax for the first five years of their wind power consumption. Wind power not purchased directly by an industrial or commercial enterprise is purchased by the electricity board at a fixed rate of 2.25 Rupees/KWh ($0.05/kWh). The rate escalates at 5% per year for the first 10 years of operation, then is held constant for 3 years before returning to a 5% escalation for the remaining 7 years of the project's expected life. The electricity board covers the cost of grid losses over the first three years, after which the equivalent charge of one percent is passed along as a grid charge for the remainder of the project life (Mathews 2004).

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